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RESEARCH ON USING HYDRAULIC TRANSMISSION SYSTEMS IN FOUR WHEELERS

C. Aditya
3rd yr, Mechanical Department, Velammal College of Engineering and Technology,
Viragnoor, Madurai, India.

Abstract*: Hydraulic transmission systems have been used to power applications involving high torque demands and reliability. In recent years, when the automobile industry started to focus on efficiency Its (hydraulic and also pneumatic) working characteristics are found to be more ideal for modern automobile power-train system rather than just in transmission of torque to the wheels. However its full capabilities of being a versatile component in modern power train systems are not still designed engineered and employed to meet conventional automobile applications. This paper is to prove the following innovative (not known to exist) concepts involving hydraulic transmission technique to have multiple purpose applications in power trains of heavy automobiles where reliability and demand for torque are usually high. The concepts involve- Hydraulic Automobile differential (with easy differential lock), Hydraulic All-wheel drive with adaptive differential lock, Two wheel drive hydraulic valve controlled variable transmission, All-wheel drive hydraulic valve controlled variable transmission, Hydraulic regenerative retardation, Hydraulic regenerative braking (known to exist), Initial torque boosting concept and hydraulic steering by reverse differential action. Most of the above concepts are not known to exist but the base principle of such transmissions' working is confirmed to be more effective for heavy duty automobiles involving high torque demands, Recently, by the leading auto industries who have also projected in hydraulic hybrids and have registered up to 60-70% of net fuel consumption of an average truck that can be saved by implementing SHEP (Stored Hydraulic Energy Propulsion) (In its power train), which is an integrated part in two of our above concepts.

I. BASIC HYDRAULIC DIFFERENTIAL ACTION (CONCEPT- NOT KNOWN TO EXIST)

The following diagrams are self explanatory and it explains that the two wheels are connected to independent axils though they are powered by a single source:
If the compressor discharge is 2Q then;

*A. CASE 1***-** At straight roads: No differential action:
At straight roads both the wheels and hence the hydraulic motors must run at same speeds. Thus the discharge is evenly distributed. Hence, One Q of discharge is directed to one hydraulic motor and other Q to the mating wheel's motor. This is explained by the following diagram.

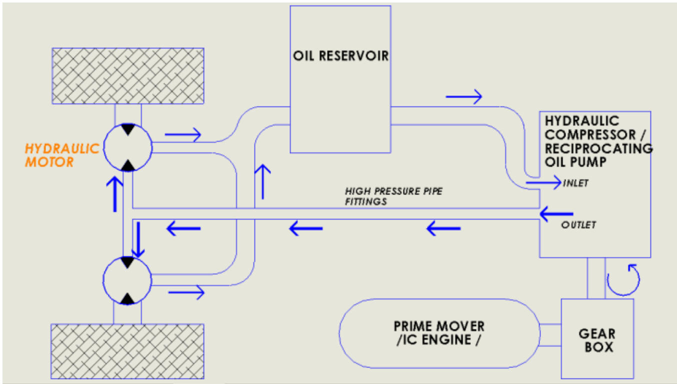

Fig 1

B. CASE2-During turns: differential action:
When turns are executed, the wheel and hence the inner hydraulic motor inner to the turning circle must run at lower speeds than its mating motor, hence the inner motor's speed reduces thus reducing the discharge through it. However the compressor discharge remains constant. Thus an excess discharge flows through the other mating motor thereby increasing its speed of rotation. Hence a Differential action is achieved.

C. CASE3-Differential lock:
Differential lock is established by connecting the two motors in series. One Q of discharge is allowed to flow through the series and the other Q of discharge is stored in an accumulator under pressure in order to maintain that the same amount of discharge flows through the motor there by avoiding sudden increase in speeds. The usage of such high-pressure accumulators will be dealt later in this paper.

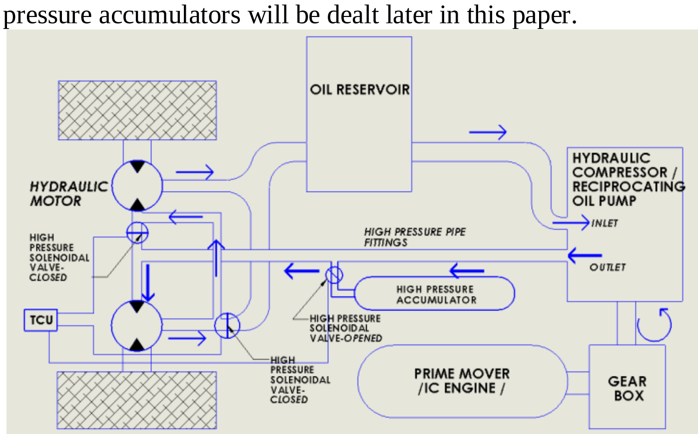

Fig 2

The following diagram explains that the above differential concept can be added to all the wheels (or more than a pair of wheels) without compromising on efficiency and without greatly increasing the transmission unit's weight.

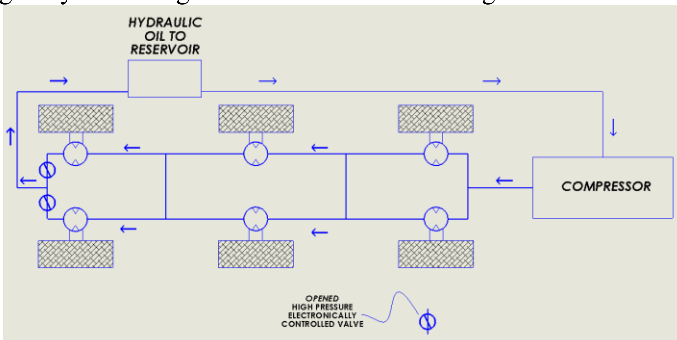

Fig 3 All-wheel Drive concept with Adaptive differential lock (Not known to exist)

II. ADAPTIVE DIFFERENTIAL LOCK CONCEPT

It means that the transmission automatically cuts off the discharge to the motors whose wheels are not on solid ground and are under slippage or punctured.

- All piping must be fitted with uni-directional flow valve
- When a wheel undergoes slipping, the network automatically locks it adaptively with or without using TCU
- Now the discharge to the locked wheel is redistributed to the wheels on solid ground
- Thus the discharge is increased to the motor on the solid ground thus resulting in increased torque acting on the wheel
- Thus when a wheel is locked ,the power to the wheels are redistributed, However the net power delivered to the wheel are equal at all times
- Thus an adaptive differential lock action is established.

A. CASE1-Without Engaging TCU:

When less than 4 wheels (in this case) are under slippage or punctured.

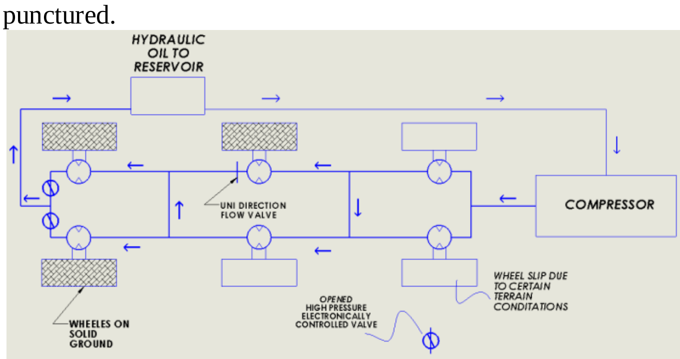

Fig 4

B. CASE2-By engaging TCU:

When greater than 3 wheels (in this case) are under slippage or punctured.

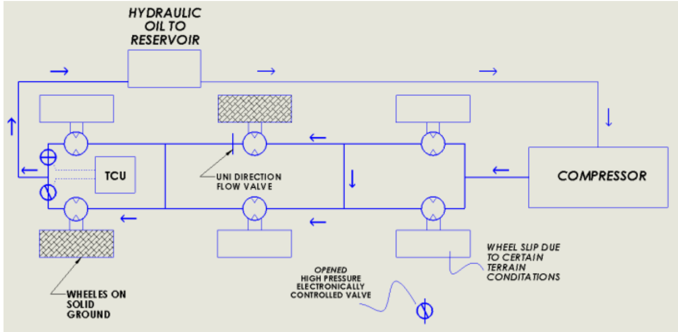

Fig 5

III. HYDRAULIC REGENERATIVE RETARDATION (Not known to exist)

- When the automobile decelerates, the CLUCH plate separates hence the mechanical power to the gearbox –compressor is cut off .Hence the discharge becomes zero
- Now the hydraulic motor turns into hydraulic pump ,powered by the running wheels of decelerating automobile
- Now this hydraulic motor pumps the oil in the same direction of flow
- The TCU gets engaged at this point and shuts the flow to the dead compressor and redirects it to a dynamo where the hydraulic flow energy is converted into electrical energy
- This electrical energy is used to recharge the battery

At standard conditions:

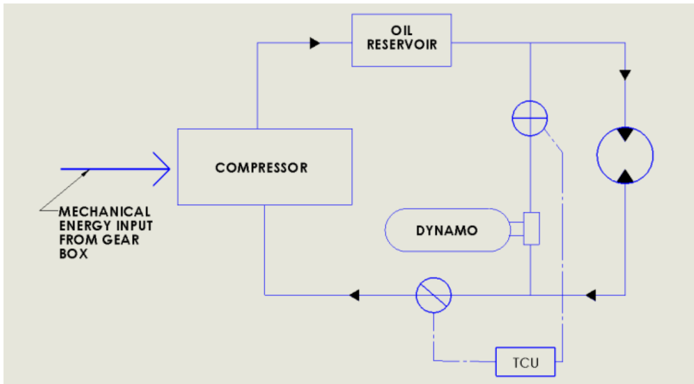

Fig 6

During Retardation:

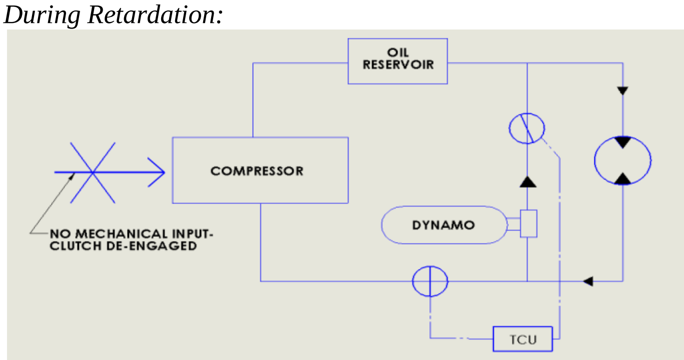

Fig 7

IV. HYDRAULIC REGENERATIVE BRAKING

(Uses SHEP concept- known to exist)

During breaking:

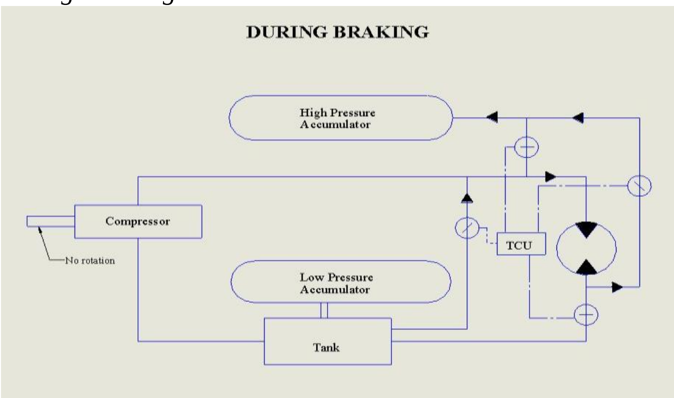

Fig 8

- During breaking, the compressor becomes dead as the clutch is disengaged but the hydraulic motor continues to rotate
- This is because during braking the oil the low pressure tank is sucked and is pumped into the high pressure tank. During this action the high pressure tank resist to accept the intake of the oil and it slows down the flow of discharge. Thus a breaking torque acts on the hydraulic motor.

Outcome:

- Braking achieved
- Oil is stored in high pressure tank for initial torque requirements

Regeneration of energy lost in braking as SHEP energy:

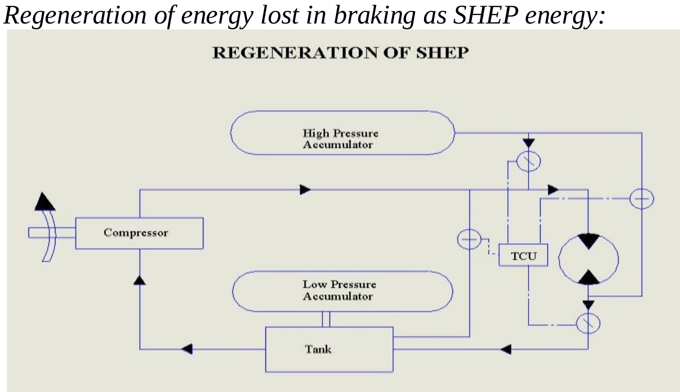

Fig 9

Now the TCU calculates the required torque demand and satisfies the demand with SHEP by controlled releasing of Stored Hydraulic Pressure from the High-pressure accumulator along by running the compressor.

V. HYDRAULIC INITIAL TORQUE BOOSTING CONCEPT (NOT KNOWN TO EXIST BUT USES SHEP TECHNIQUE)

Initial torque demand will be high for fully loaded trucks under certain conditions. Hence during from rest to crawling of such trucks need addition torque .this concept may be employed under such circumstances

Action:

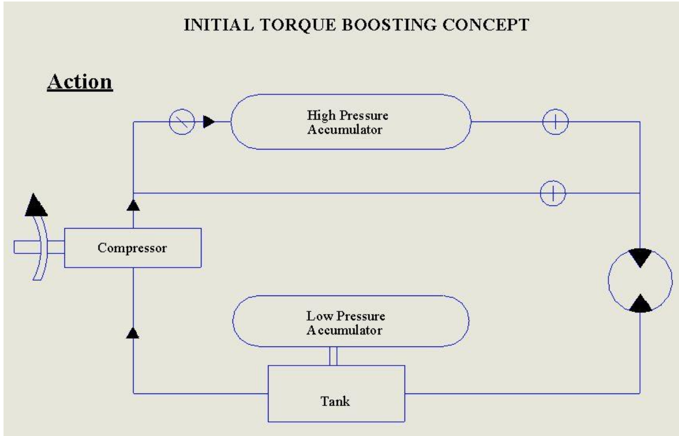

Fig 10

- When the truck is about to crawl from rest high torque demand then this process will be executed.
- TCU shunts the flow to the hydraulic motor by closing the valves as shown.
- Compresses the oil into it by running the compressor .thus the hydraulic pressure in that accumulator is increased.
- When TCU senses that enough SHEP, required for the power train is generated into the high pressure accumulator as hydraulic energy, it shuts the inlet valve to the accumulator.

Reaction:

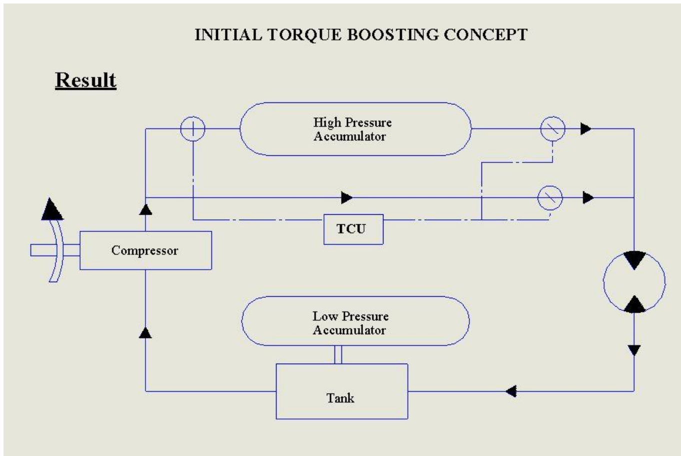

Fig 11

- Now the TCU redirects the discharge from the compressor back to the motor for it propulsion
- The extra torque demand is met by controlled releasing of SHEP from the high pressure accumulator.
- TCU later shuts the H-pressure accumulator when the excess torque demand is satisfied.
- Simultaneously the excess discharge from the high-pressure accumulator feeds the low pressure accumulator/ oil tank, there by equalizing the pressure.
- Thus two power source propels the motor

VI. HYDRAULIC STEERING BY REVERSE DIFFERENTIAL ACTION

forward differential action: When an automobile turns using conventional “rack and pinion (or with power assist) setup”—the differential allows the et of wheel to rotate at inner turning circle. Reverse differential action When a set of wheel is made to run at higher speed than it’s mating set of wheels, the automobile tends to turn in the direction towards the line joining speed Thus steering action can be achieved of ‘reversing the differential action’

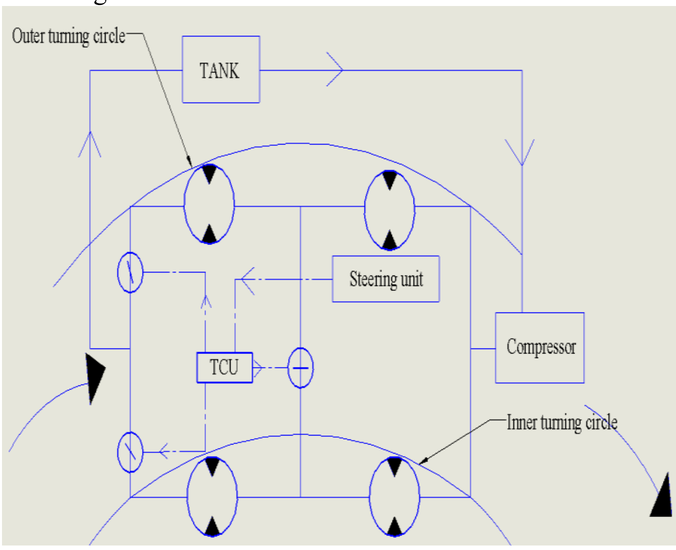

Fig 12

Action:

- During Turing ,the TCU engages and shuts the solenoid valve as shown in the diagram
- Thus the either set of wheel is made to be run at same discharge.
- Now one valve is adjusted in order to decrease the flow to one set of wheel thereby decreasing the speed on one side
- Hence a steering action is achieved.

VII. HYDRAULIC VARIABLE TRANSMISSION BY EMPLOYING DIFFERENT TORQUE-CONFIGURED HYDRAULIC MOTORS

This concept is about applying hydraulic transmission technique for varying the torque applied to the wheels, similar to Varying the torque –speed delivered to the differential by using conventional gear box.

A. CASE 1: FOR LOW GEAR EQUIVALENT PROPULSION

1) A high torque configured Hydraulic motor depending upon specific power train requirements is coupled to the wheels of Pair #1.
2) Now the reciprocating Pump is run and for the same amount of its discharge rate flowing through the High-torque configured motor, it drives the wheel by applying high torque.
3) Thus low gear equivalent propulsion is established in this setup.

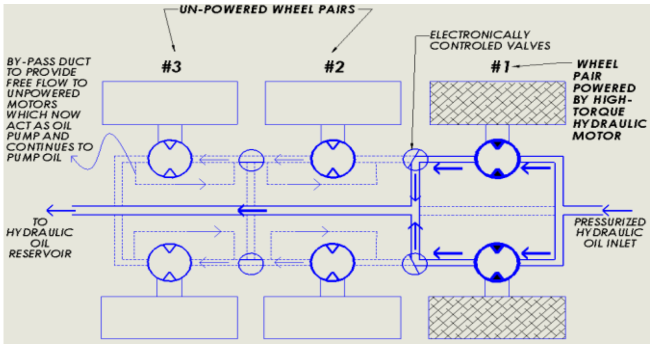

Fig 13

1) By-pass tube is used as shown to provide hydraulic oil circulation to unpowered motors (#2 and #3) in order to avoid restriction in the flow of oil through these motors which now act as oil pumps.
2) The TCU directs the flow through the pair #1 motors until the vehicle attains the required momentum(velocity).

B. CASE 2: FOR MID GEAR EQUIVALENT PROPULSION

- When the vehicle has attained the required momentum(velocity), the TCU redirects the flow to the pair #2 hydraulic motors of mid range torque-speed configuration.
- However the same rate of discharge from the reciprocating pump continues to flow through each motor of pair #2 and hence the vehicle propulsion is continued.
- Thus mid gear propulsion equivalent is established.

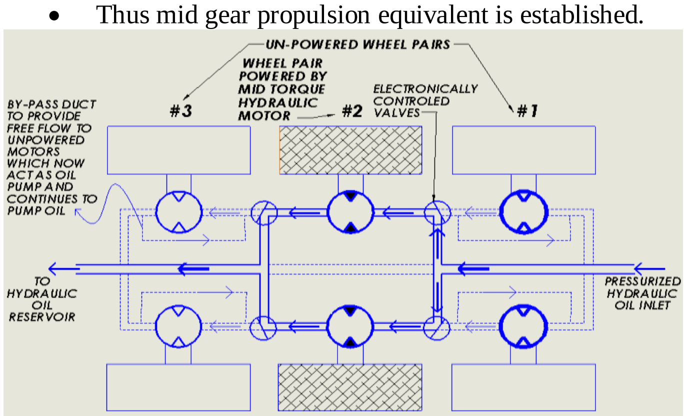

Fig 14

As in previous case, the By-pass tube is used as shown to provide hydraulic oil circulation to unpowered motors (#1 and #3) in order to avoid restriction in the flow of oil through these motors which now act as oil pumps.

C. CASE 3: FOR HIGH GEAR EQUIVALENT PROPULSION

- When the vehicle has attained the required momentum(velocity), the TCU redirects the flow to the pair #3 hydraulic motors configured for low torque-high speed propulsion.
- Thus High gear propulsion equivalent is established.

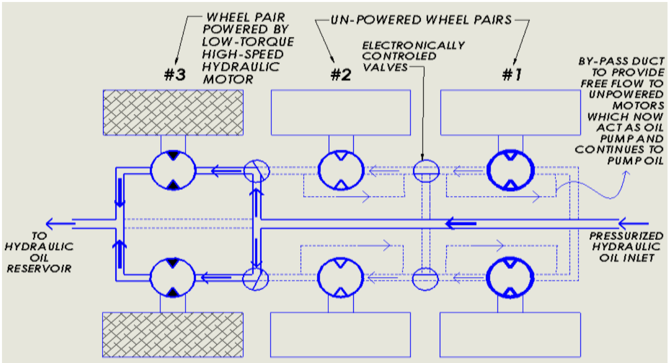

Fig 15

other aspects in case-3 are similar to the previous two cases

Advantages** of replacing conventional transmission with hydraulic drive train are practically obvious. Some additional merits are given below;

- The weight of the hydraulic drive train for AWD will fairly be less than the weight of conventional set-up for the same application in case of more than 4x4 drive train systems. Hence efficiency is improved under implication of such systems.
- Differential-lock is established easily in both 2x2 and AWD drives (adaptive differential lock) without any annoying 'click' sounds like in conventional Diff lock which is a major demerit of existing systems.
- Efficiency of hydraulic diff will be higher than LSD (Limited Slip Differential) as Clutch mechanism is not employed as in LSD.
- Wear and Tear is minimum when compared with conventional transmission and diff lock systems.
- Ground clearance is drastically increased as there are no drive axils connecting the wheel pair through conventional differential, which will be very helpful in off-road applications&.
- Fault tolerance is high as if one motor fails, the discharge from the reciprocating oil pump can be redistributed among other wheel-motors with the help of TCU.

** -when these concepts are employed practically, further more merits and also demerits of such systems can be explored. & -Proved to be more feasible for practical off road trucks (like TATRA® off-road trucks) by leading automobile manufacturers.

All the concepts stated above may be improved industrial concepts or practically new concepts. however they are Genuine in their own way of working. Maximum effort has been carried out by the authors to make sure that the above concepts are conceptually new or may be not the exact replica of existing ones, if any. Further clarifications may be provided on request.

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The reference web links and books provided above contains related 'power transmission' concepts employing similar principle, which the author used for his coarse study on existing transmission techniques. the author does not guarantee the quality and accuracy of the information provided by these websites and books. Further references may be provided on request.

